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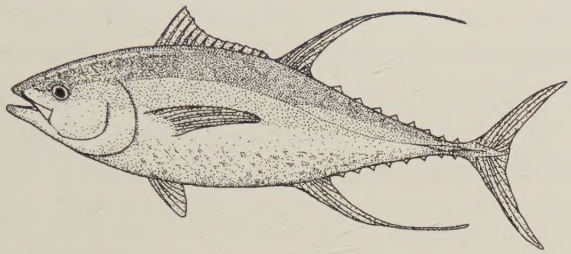
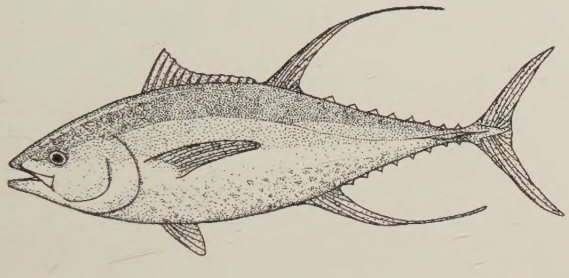
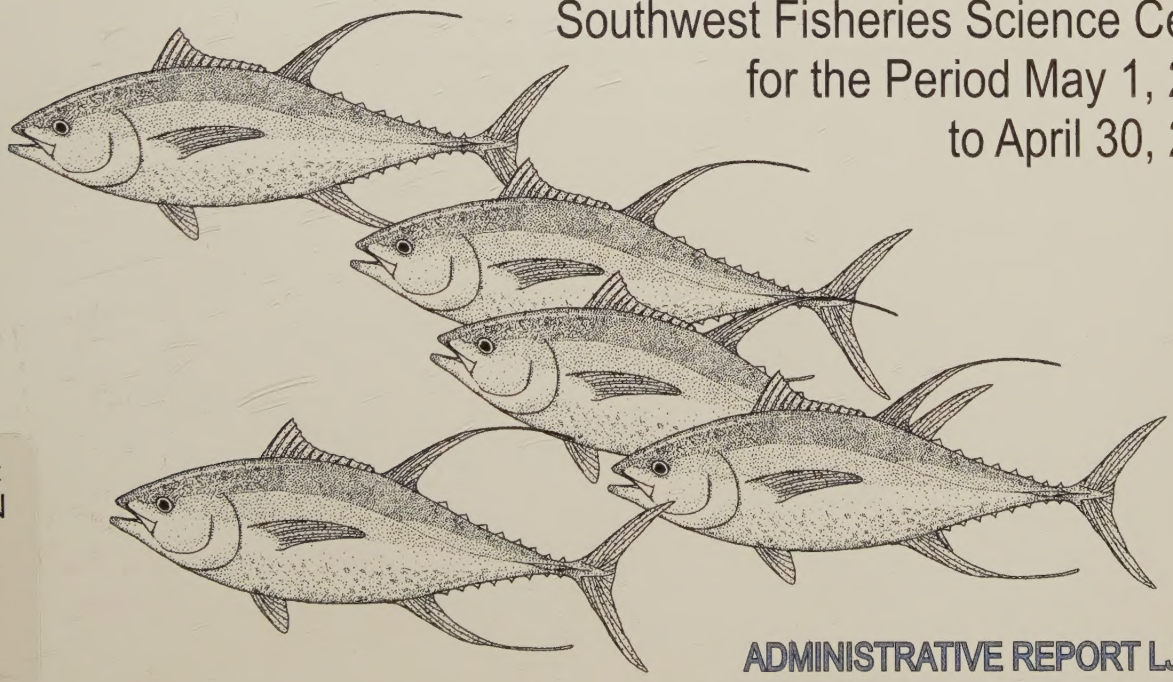
National Marine Fisheries Service
Southwest Fisheries Science Center

Director's Report to the 57th Tuna Conference





On Tuna and
Tuna-Related Activities at the
Southwest Fisheries Science Center
for the Period May 1, 2005
to April 30, 2006



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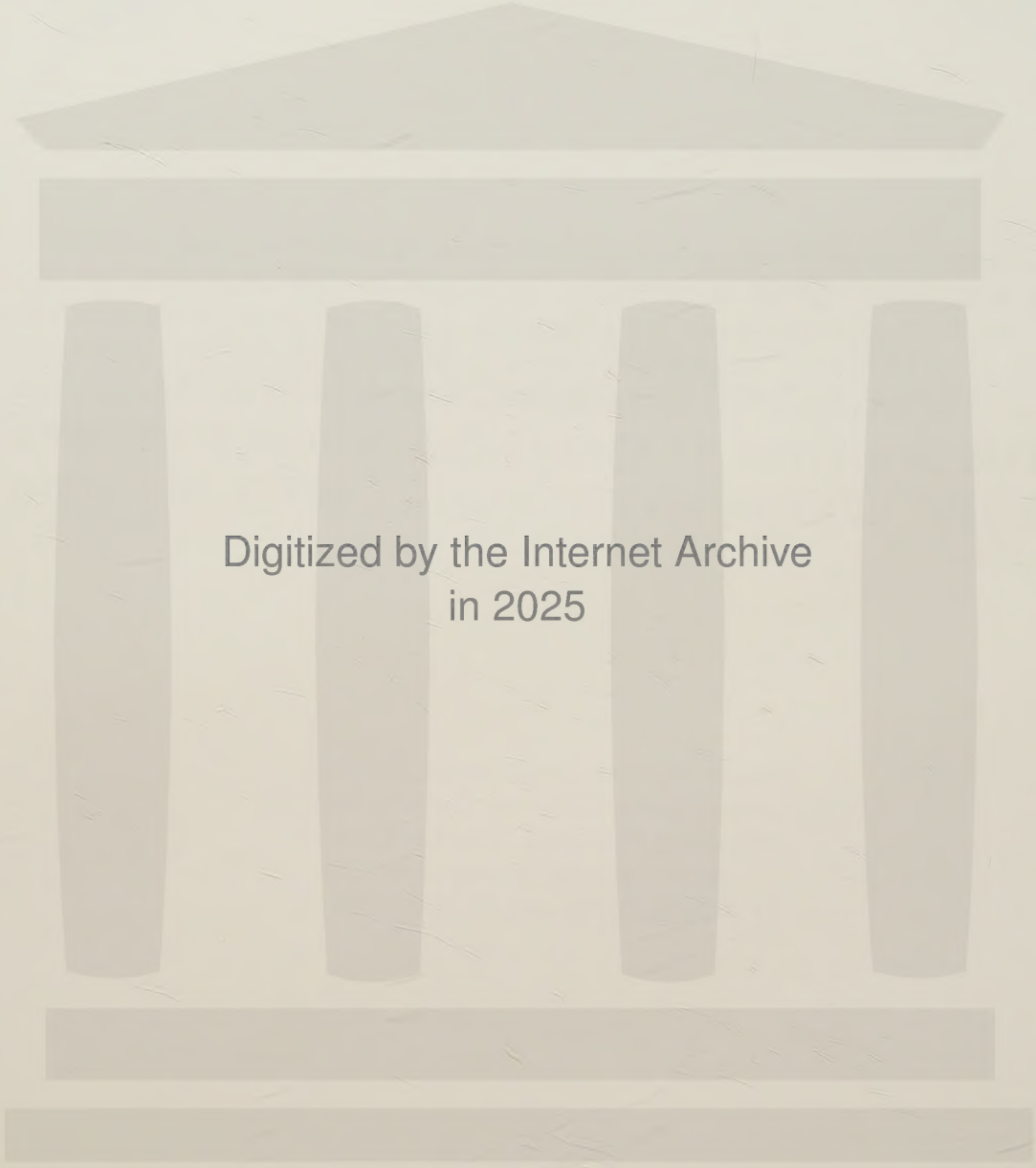

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Introduction

The report which follows summarizes research conducted by the Southwest Fisheries Science Center relating to tropical tunas, albacore, billfishes, oceanic sharks and protected species associated with their fisheries for the period May 2005 through April 2006. The Center's biological, economic, and oceanographic research was focused on supporting the information needs of regional fishery management councils, international scientific working groups and committees, and the National Marine Fisheries Service. Major tuna-related activities included stock assessments, socio-economic research, research on interactions between fisheries and protected species, and mathematical modeling of fish movements and fishery interactions. The data collection and analysis were aimed at maintaining healthy U.S. and world fisheries, populations of protected marine species, and fish habitat, and ensuring that the most effective fishing regulations and international treaties are carried out. In addition, Center scientists were active in tuna-related international forums such as the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, and the Scientific Committee of the Western and Central Pacific Fisheries Commission.

William W. Fox Jr., Ph.D.
Science Director, Southwest Region
National Marine Fisheries Service

May 2006
La Jolla, California

I. U.S. TUNA PURSE SEINE FISHERY IN THE WESTERN-CENTRAL PACIFIC

The National Marine Fisheries Service (NMFS) collects and manages data from the U.S. purse seine fishery for tropical tunas in the western-central Pacific, as part of U.S. obligations under the South Pacific Regional Tuna Treaty. Information from U.S. vessels licensed to fish under the treaty is collected by the NMFS office in American Samoa and transmitted to the Southwest Fisheries Science Center (SWFSC) in La Jolla, California, where scientists computerize logbooks, landings, and biological data from the fleet.

In 2005, the U.S. purse seine fleet size fell to the lowest level since the start of the treaty in 1988. Only 15 U.S. vessels fished in 2005. This is down from 21 vessels fishing in 2004 and continued a downward trend in fleet size that started in 1998. Even with the decrease in fleet size in 2005, total catch (74,300 metric tons, t) increased 8% over that recorded in 2004 (68,800 t). Skipjack tuna dominated the 2005 catch (70%) as in previous years, followed by yellowfin tuna (20%), and bigeye tuna (10%).

Sets on floating objects (logs and fish aggregation devices) in 2005 were at 56% of all sets, a 26% decrease from the 76% recorded in 2004. Sets on free-swimming schools of tuna accounted for 43% of the sets in 2005, an 87% increase over 2004 (23%). The larger fish associated with sets on free-swimming schools contributed to the 8% increase in total catch. The increased use of floating object sets in 2005 also decreased the number of days per trip (-24%), sets per trip (-3%), and trips (-7%) over those recorded in 2004. The overall catch rate increased to 27 t per day fished in 2005, an 80% increase over the catch rate in 2004 (15 t per day fished).

Fishing effort in 2005 shifted north with a slight movement east from the distribution of 2004 fishing effort. Higher levels of fishing effort (6-28 days) in 2004 were concentrated in 1° squares distributed along an east-west line between 0° and 10°S. In 2005, there were very few 1° squares with higher levels of fishing effort, and effort in general was spread over a slightly larger area of the western-central Pacific than in 2004.

Biological samples collected from the tuna catch provided estimates of sizes of fish caught on a species-by-species basis. Length measurements were taken from (29,689) yellowfin, skipjack, and bigeye tunas, a decrease of 24% from the number of fish sampled in 2004 (39,044).

II. REGIONAL FISHERY MANAGEMENT ORGANIZATION ACTIVITIES

Center scientists continue to work cooperatively with colleagues from other nations on marine resources of mutual concern, including tropical tunas, albacore, billfishes, and other large pelagic fishes. Following are highlights of some of the meetings and other activities that took place during the year in which Center scientists participated:

First Meeting of the WCPFC Scientific Committee – SWFSC scientists joined scientists from the NMFS Pacific Islands Fisheries Science Center and others to serve on the U.S. delegation to the first regular session of the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC), which was held in Noumea, New Caledonia, August 8-19, 2005. The U.S. delegation was invited to the

meeting as an observer and participant. Full U.S. membership in the WCPFC is underway.

Scientists and fishery officials from 23 WCPFC member countries and from about 10 observer countries and organizations participated in the session, which was led by the chairman of the Scientific Committee, Sung-Kwon Soh. The extensive agenda for this first meeting focused largely on reviewing stock assessments of yellowfin (*Thunnus albacares),* bigeye (*T. obesus),* and skipjack (*Katsuwonus pelamis)* tunas of the western Pacific Ocean and albacore of the South Pacific; developing advice on conservation and fishery management measures; and developing policies to guide administrative matters of the Scientific Committee. A report of the meeting is available on the WCPFC website (*http://www.wcpfc.org*).

Significant conclusions of the Scientific Committee meeting included condition of the stocks. For this, the Scientific Committee compared stock assessment results against MSY-based biological reference points. The results indicated that both bigeye (2004 yield of 125,900 t) and yellowfin (2004 yield of 413,200 t) tuna stocks are experiencing overfishing but are not in an overfished state. The skipjack tuna stock, with a 2004 yield of 1.4 million t, is experiencing neither overfishing nor is the stock in an overfished state. Results for South Pacific albacore indicated recent levels of catch (2004 yield of 55,000 t) and effort are sustainable, even with some increases in catch.

ISC Meeting Hosted by SWFSC in La Jolla – The sixth meeting of the of the International Scientific Committee (ISC) for Tuna and Tuna-like Species in the North Pacific Ocean was held in La Jolla, California, March 23-27, 2006. The SWFSC hosted the meeting that included associated ISC working group meetings earlier in the week. Scientists from Canada, Chinese-Taipei (Taiwan), Japan, Korea, Mexico, United States, Inter-American Tropical Tuna Commission (IATTC), and Secretariat of the Pacific Community participated. Non-members participating were from the Philippine Bureau of Fisheries and Aquatic Resources and the Scientific Committee of the WCPFC.

The U.S. delegation to this sixth meeting was led by Science Director William Fox and consisted of NMFS scientists from the SWFSC, Pacific Islands Fisheries Science Center, and Pacific Islands Region. Gary Sakagawa, Assistant Center Director for Fishery Management Programs, chaired the meeting, which focused largely on review of outputs of subsidiary bodies, including stock assessment results and achievements, developing advice on stock conservation, and providing guidance on work plans of the subsidiary bodies.

The ISC noted the progress made to date. Results of exploratory stock assessments were available for review. The results require additional work before being definitive; nonetheless, taking into account recent trends in the fisheries, life history characteristics of the species, and experience from analogous fisheries, the ISC concluded that stocks of North Pacific albacore (*Thunnis alalunga)* (2004 catch of 86,100 t), Pacific bluefin tuna (*T. orientalis)* (2004 catch of 21,700 t), and striped marlin (*Tetrapterus audax)* (2004 catch of about 12,700 t) in the North Pacific are heavily exploited. Preliminary information on fishing mortality rates for recent years suggests that rates are excessive for sustaining high yields from the stocks. The ISC, therefore, recommended that fishing mortality not be increased above recent levels for Pacific bluefin tuna and striped marlin as a precautionary measure. For North Pacific albacore, the ISC noted that its 2005 advice on the North Pacific albacore stock is still applicable;

that is, recent fishing mortality appears to be high and should not be increased further. It noted that the resolutions passed by the IATTC and WCPFC limiting fishing mortality to recent levels are consistent with this 2005 advice.

The ISC reviewed work plans for its six working groups and made adjustments to the plans, including assigned objectives and schedule of meetings. Priority was assigned to completing up-to-date stock assessments within a year or two for the principal species (North Pacific albacore, Pacific bluefin tuna, and swordfish, *Xiphias gladius*) and in time for the ISC to review at its next meeting in July 2007. This action was largely undertaken in order for the ISC to provide timely scientific advice to the Northern Committee of the WCPFC under terms of an agreement between the ISC and WCPFC.

Collaboration on Pacific Bluefin Tuna Research – In 2005, SWFSC scientists began assessment efforts on Pacific bluefin tuna. Before and during the ISC Bluefin Working Group meeting in early 2006, the SWFSC team worked closely with other members of the working group in developing an assessment database, deriving indices of abundance, and exploring alternative stock assessment models. In particular, SWFSC scientists took the lead in developing a fully integrated forward simulation model using Stock Synthesis 2. Much of this work is continuing in efforts to improve the bluefin stock assessment.

Collaboration on Fisheries Statistics – The SWFSC, in cooperation with various regional fishery management organizations, has submitted landings and number vessels (Category I), summary 1° or 5° monthly catch and effort (Category II), and summary 1° or 5° monthly size frequency (Category III) data. Regional fishery management organizations receiving data in 2005 included the IATTC, ISC, and WCPFC. The data will be used by the regional fishery management organizations to assess the status of various fish stocks, including bigeye tuna, yellowfin tuna, albacore, bluefin tuna, swordfish, and striped marlin. The SWFSC helped the ISC establish its database by reformatting and transferring Category II and III data maintained by the ISC Albacore Working Group. Also, the SWFSC developed an ftp site to be used by the ISC to collect and distribute Category I, II and III data until the ISC data system is in place.

Pacific Fishery Management Council Activities – Suzy Kohin, Steve Stohs and Dale Squires of the SWFSC currently serve on the Highly Migratory Species (HMS) Management Team of the Pacific Fishery Management Council. The team met several times in 2005 and early 2006 in support of the recently implemented fishery management plan for U.S. West Coast HMS fisheries. With implementation of the fishery management plan, shallow set swordfish longline fishing was prohibited for U.S. West Coast-based vessels. The team was tasked early on to develop an amendment to the fishery management plan to allow for a limited entry longline fishery for swordfish. However, the Hawaii-based swordfish longline fishery reopened in 2005 with a limited number of sets permitted and restrictions on the numbers of loggerhead and leatherback sea turtle interactions. Virtually all of the vessels affected by the U.S. West Coast prohibition had a permit to fish swordfish under the Western Pacific Fishery Management Council's pelagics fishery management plan. Hence the urgency to develop a longline amendment lessened. The HMS Management Team, therefore, focused its efforts on conducting analyses to guide the Pacific Fishery Management Council in choosing alternatives for opening a segment of the California/Oregon/Washington drift gillnet fishery which would allow fishing in restricted areas without jeopardizing protected species. To this end, in March 2006, the Pacific Fishery Management Council approved an exempted

fishing permit application to be considered for authorization by the NMFS that would allow a limited number of vessels to fish in the currently closed area under restrictions on protected species interactions. The Pacific Fishery Management Council also approved for NMFS consideration an exempted fishing permit for a single vessel to conduct longline fishing for bigeye tuna and swordfish within the U.S. West Coast Exclusive Economic Zone (EEZ).

Several other highly migratory species matters that came before the Pacific Fishery Management Council were referred to the HMS Management Team for analysis and comment. They included an NMFS plan to end bigeye tuna overfishing in the Pacific Ocean, notice of need to limit fishing effort on North Pacific albacore to recent levels, and submission of a 2005 Stock Assessment and Fishery Evaluation (SAFE) Report. The team provided guidance on the plan to end bigeye tuna overfishing and is working on analyses of the current U.S. albacore troll fleet fishing effort. Finally, the team produced the first SAFE report in the fall of 2005.

III. HIGHLY MIGRATORY SPECIES DATA COORDINATION

A data coordination team has been working since 2002 towards better coordination of collection and maintenance of HMS data at the NMFS Pacific Islands Fisheries Science Center, Pacific Islands Region, Southwest Region and SWFSC. The team is co-chaired by staff from the Southwest and Pacific Islands Fisheries Science Centers. During September 2005, the team met to discuss progress on resolving issues that were identified at its first annual meeting and to identify any new issues. Significant progress had been made on establishing a data portal (*http://swfscdata.nmfs.noaa.gov*) for sharing information and for allowing public access to summary information. The site contains an HMS data catalog with metadata descriptions and summaries of each data set maintained by the members. Meeting minutes, data submission guidelines, minimum requirements for data collection, and data management policies are also available on the site although undergoing development. Special working groups have been organized to develop data management and collection guidelines and are continuing work on completing a data catalog. The next annual meeting of the HMS data coordination team is scheduled for August 2006 in Honolulu, Hawaii.

The team has been also working closely with the national Fishery Information System (FIS) project in NMFS headquarters. A member of the SWFSC staff is on the FIS Program Management Team and has helped complete an FIS program plan. The Program Management Team is currently working on developing a project proposal system for the 2007 budget cycle. This will allow the team some transparency in their project selection process. In 2006, FIS funded three projects that will directly affect the SWFSC. The first is a project to develop policies and standards for development of electronic logbook projects. The second is a pilot project for electronic fish dealer reporting on the West Coast (Oregon, Washington and California). The third is a "one stop shop" project to enable national compilation of landings data for the United States. The FIS has also developed an InPort system to archive metadata and has provided funds to populate this system with data from all NMFS Regions.

Another FIS data reconciliation project has been started to reconcile logbook data with Pacific Coast Fisheries Information Network landings data and cannery receipts databases. Reconciliation of these data will increase data quality substantially.

HMS information technology specialists at the SWFSC are also improving data collection methods. Electronic calipers (1.6 m) were field tested by port samplers in Oregon and Washington in 2005. Modifications were made to the units based on the test, and the port samplers will use the calipers for the entire 2006 albacore sampling season. This tool should increase sampling efficiency and eliminate transcription errors that can occur with hard copy length-frequency collection procedures. Specialists have also developed a stand-alone electronic logbook software application that was deployed and tested onboard a group of U.S. albacore troll vessels during the 2005 fishing season. Modifications are being made to the electronic logbook, and the modified versions will be deployed on a number of boats for the 2006 season. Vessel captains will enter data directly to the logbooks; the daily records will be stored on disk and the disk will be transferred to the SWFSC upon completion of a trip.

The SWFSC HMS team continued to process and load HMS data onto the Center's new database. South Pacific Tuna Treaty logbook, landings, size and species composition data for 1988 to the present have been loaded to the system. U.S. albacore troll logbook and size frequency data are currently being transferred to the system. Data entry forms (web-based) have been developed for these two data sets; data management forms have been developed for the system and are currently being tested. In 2006, harpoon, longline and gillnet fishery data will be added to the database. The group will also be adding purse seine and longline observer data to the system and developing data entry and summary capabilities in 2006. The observer data will be used to interface with a national bycatch and discard data system to prepare a national bycatch and discards report. The HMS database system and the proposed national system are in Oracle.

IV. PACIFIC ALBACORE FISHERIES

U.S. troll vessels have fished for North Pacific albacore since the early 1900s and for South Pacific albacore since 1986. North Pacific albacore fishing areas range from Vancouver Island to the coast of Baja California and from the U.S. West Coast to approximately 160°E. The fishing season begins in late April and can last into mid-November. The size of the troll fleet for a season ranges from 500 vessels to over 1,000 vessels. About 734 U.S. troll vessels fished for North Pacific albacore in 2004.

Fishing areas for South Pacific albacore extend eastward from the east coast of New Zealand to approximately 110°W and between 30°S to 45°S. This fishery begins in late December and continues until early April of the following year. The international troll fleet in the South Pacific for an albacore fishing season consists of 20 to 60 vessels. For the 2004-05 season, 10 U.S. troll vessels fished for albacore in the South Pacific, one less than for the 2003-04 season. Bycatch species are sometimes reported in vessel logbooks and they include yellowtail, dolphinfish, and skipjack, yellowfin, bigeye and bluefin tunas.

The NMFS routinely processes the following information for use in stock assessments and for fishery monitoring: (1) landings obtained from U.S. West Coast states; (2) logbook data collected from cooperating fishermen; and (3) length-frequency data obtained through port sampling of U.S. albacore troll and baitboat vessels operating in the Pacific Ocean

The SWFSC provides logbooks to fishermen, who record fishing information and return the logbooks to the SWFSC. Beginning in April 2005, logbooks have become mandatory under the requirements of a new HMS fishery management plan. Length-frequency data are collected through a Pacific States Marine Fisheries Commission contract to Washington, Oregon and California state fisheries agencies and from the NMFS office in American Samoa. Statistics from these sources were analyzed during the year by SWFSC staff and summarized in a report issued in August 2005. Highlights of the report are given below.

Summary of U.S. North and South Pacific Albacore Troll Fisheries – U.S. troll vessels landed 13,346 t of North Pacific albacore in 2004, compared to 14,102 t landed in 2003. Annual catches over the last 10 years averaged 12,248 t. The most productive fishing areas in 2004 were in waters off Washington and Oregon and offshore between 160°E and 170°E. U.S. catches of South Pacific albacore decreased from 1,678 t in the 2002-03 season to 995 t in the 2003-04 season. South Pacific catches averaged 1,706 t over the past 10 years.

Catch per unit of effort (CPUE) in the North Pacific fishery has increased steadily, from 36 fish per day in 1999 to 87 fish per day in 2004. Total effort increased slightly, from 23,442 days fished in 2003 to 23,979 days fished in 2004. CPUE for the South Pacific fishery has been increasing since the 2000-01 season to115 fish per day in 2003-04, while effort has been decreasing, from 6,377 days fished in 2000-01 to 1,475 days fished in 2003-04.

A total of 30,892 albacore were measured during the 2004 North Pacific season. The average fork length of sampled albacore in 2004 is 68 cm (14 lb or 6.4 kg), compared to 73 cm (18 lb or 8.0 kg) in 2003. A single size-class mode is centered at 66 cm fork length (3 years old) in the North Pacific length-frequency samples.

During the 2003-04 South Pacific season, a total of 811 albacore were measured. The average fork length of South Pacific albacore that were sampled is 66 cm (13 lb or 5.8 kg), compared to an average fork length of 71 cm (16 pounds or 7.3 kg) from the 2002-03 season. Because of the low sample size, individual size-class modes were difficult to distinguish.

Cooperative Research with the American Fishermen's Research Foundation – SWFSC scientists are working with the American Fishermen's Research Foundation (AFRF) on monitoring programs and other research efforts to improve knowledge of the biology and migration of North Pacific albacore in the waters off the U.S. Pacific Coast. The cooperative research includes:

North Pacific Albacore Biological Data Sampling Program – Since 1961, a biological data collection program, or port sampling program, has been in place for collecting size data from albacore landings made by the U.S. and Canadian troll fleets at ports along the U.S. Pacific Coast. State fishery personnel collect the biological data from Washington, Oregon and California following sampling and data processing instructions provided by the SWFSC, where the database is maintained. A total of 458 fishing trips and 36,974 fish were sampled in 2004. In recent years, fishermen have also collected biological data during selected fishing trips and with AFRF support to augment data collected through the port sampling program. After a training session, fishermen provided a randomly selected length distribution for randomly selected fishing trips that

landed catches at ports in California, Oregon and Washington. Participation in this program has been increasing, with 720 length measurements taken in 2004. AFRF members and SWFSC scientists designed new measurement kits in 2004 for the fishermen. The sample information provided by the fishermen was found to be generally similar to that collected through the port sampling program.

North Pacific Albacore Logbook Data Sampling Program – A logbook sampling program also has been in place through the AFRF since 1961, whereby albacore troll fishermen voluntarily submit their fishing records to the SWFSC. The implementation of a new HMS fishery management plan in 2005 requires the submission of a logbook from each trip that a participant in the fishery makes. These data are primarily used to develop relative indices of abundance, which subsequently provide valuable auxiliary information for fine-tuning stock assessment models. Fishing records are submitted directly to the SWFSC; in 2004, the U.S. troll fleet submitted 585 logbooks. A database for logbook data is also maintained at the SWFSC.

North Pacific Albacore Archival Tagging Project – A long-term archival tagging project with SWFSC and AFRF support was undertaken during the 2001 albacore fishing season to document details regarding North Pacific albacore migration, behavior, and habitat preferences that are only generally understood (i.e., to determine exact migration routes of juvenile fish, 2-5 years old, and to determine time, temperature, and depth characteristics of the migrating fish). The project was structured as a five-year program that entails tagging approximately 120 fish in each year for a total deployment of 500 tags.

A total of 384 tags have been deployed through 2005 and 15 tags have been recovered. The tagged fish, ranging from 57 to 110 cm fork length, were captured near the surface with commercial lift poles, hand lines, or rod and reel. Deployments were made off the coasts of southern California and northern Baja California, Mexico, and in Pacific Northwest waters during the summer months. The average time at liberty for tagged fish was 340 days. The data are beginning to demonstrate where animals are distributed and how they use their environment in California Current waters in the summertime and adjacent waters during the rest of the year. All fish exhibited a similar diurnal diving pattern of repetitive deep diving during the day while remaining near the surface at night. Dives routinely exceeded 200 m in depth. At the extreme, one fish dove to a depth of 1,200 m. Ten of the 15 tag recoveries were made in 2004. The large number of tag recoveries within a short time period was an unexpected surprise.

As more tags are returned, the data will assist in refining our knowledge of the North Pacific albacore stock structure, behavior, movement, and the habitat use patterns of juvenile albacore — information that is essential to improving stock assessments. During fiscal year 2006, the tagging team plans to deploy an additional 110 tags off the Oregon and Washington coasts.

International Collaboration on North Pacific Albacore Research – The SWFSC hosted the first meeting of the ISC Albacore Working Group (formerly the North Pacific Albacore Workshop), which was held in November-December 2005 in La Jolla, California. Researchers from Japan, Taiwan, Canada, and the IATTC attended that meeting. The meeting addressed four broad areas of research: (1) improvement of stock assessments through critical review of input data and modeling platforms used in population analysis; (2) appropriate biological reference points for potential management

of the stock; (3) research studies needed to improve knowledge of albacore biology; and (4) maintenance and improvement of the ISC Albacore Working Group database catalog, which contains catch, length, and catch and effort information collected from the various international fleets that harvest the stock.

Scientists from the SWFSC presented papers that addressed various topics, including formal stock assessments of the albacore population that inhabits the North Pacific Ocean, issues surrounding the albacore group's scientific information exchange and centralized databases, ongoing development of fishery statistics applicable to the U.S. troll and longline fisheries, ongoing research regarding movement and distribution of juveniles based on archival tag deployments, and development of a Pacific Ocean-wide biological sampling program that would generate timely and accurate estimates of maturity.

Work continues concerning population analysis efforts based on a fully integrated, length-based and age-structured modeling platform (Stock Synthesis 2), which in the near future is expected to become the formal model for assessing the status of the albacore stock in the North Pacific Ocean; currently, a robust baseline model configuration has been developed. In this context, an intersessional meeting will be held in July 2006 in Nanaimo, B.C., Canada, to review and develop sample data (i.e., time series of catch, catch and effort, and length and age distributions) used in population models, both for purposes of backward simulation (VPA) and forward simulation (length-based, age-structured) estimation methods. Finally, the next formal assessment-related meeting of the ISC Albacore Working Group will be held in Shimizu, Japan, in late 2006.

V. IDCPA RESEARCH CONDUCTED BY THE SWFSC

Research conducted under the International Dolphin Conservation Program Act (IDCPA) during 2005 was focused to determine the potential roles of the fishery and ecosystem in the apparent lack of recovery by depleted dolphin stocks in the eastern tropical Pacific Ocean (ETP) with significant reductions in dolphins killed by the monitored ETP tuna purse seine fleets. Activities included (1) data analyses, processing and publication; (2) the first in a series of NMFS/IATTC joint workshops on bycatch reduction; (3) a small purse seine vessel monitoring and observer program via contract; and (4) longer-term research planning.

Data Analyses, Processing and Publication – The SWFSC's investigations of dolphin stocks historically depleted by the ETP tuna purse seine fishery (pantropical spotted and spinner dolphins) are conducted with an ecosystem approach. In addition to investigating the status and trends of these dolphin stocks, auxiliary projects are conducted to improve our understanding of their surrounding environment. Data analyses, processing and publications in 2005 included (1) direct work on depleted ETP dolphin stocks, (2) investigations of dolphin energetics, and (3) research on non-depleted ETP cetaceans.

Depleted Dolphin Stocks – The SWFSC conducted line-transect research cruises in 1986 through 1990, 1998 through 2000, and in 2003 to investigate pantropical spotted and spinner dolphin stocks. From data collected on these cruises, abundance and trends of these stocks were estimated and evaluated through 2000. Line-transect sightings data from the 2003 monitoring cruise were carefully edited and processed, and updated abundance estimates were published in 2005.

Further enhancements were made to a model designed to estimate the exposure of dolphins to the tuna fishery in the ETP. This model will be central to an upcoming series of examinations on the relationship of fishery exposure and potential individual and population-level effects such as indicators of stress, calf production, and behavior. An initial paper describing the model and demonstrating some of its properties will be submitted by the end of summer 2006.

Work was begun on a Bayesian examination of a suite of single and two-phase models to describe growth in cetaceans. Initial runs have been using data from common dolphins (*Delphinus delphis*); however, later studies will include both spotted and spinner dolphin data (*Stenella attenuata and S. longirostris*). The results of this study will provide a better understanding of key features of patterns of cetacean growth.

A comprehensive life history study is in progress to update vital parameters for eastern and whitebelly spinner dolphins. This study is improved over previous studies primarily for three reasons: (1) the sample size is much larger (~1,200 specimens vs. ~250 specimens for each subspecies); (2) ages were estimated based on a calibration study; and (3) sample preparation and handling was improved. Updated life history information may provide insight into the lack of expected recovery for these subspecies.

The results of a genetic analysis of population structure of coastal spotted dolphins (*Stenella attenuata graffmani*) in the ETP were reported. Both mitochondrial DNA sequences and microsatellite loci indicated the presence of four distinct populations from northern Mexico south to Ecuador and Peru. Except for the northernmost population, these populations were also found to be distinct from samples of offshore spotted dolphins (*S. attenuata attenuata*). This is the first study to show evidence of subdivision in this population, suggesting that further studies are needed to identify proper stock boundaries for management.

Dolphin Energetics – During the period May 2005 through April 2006, several studies initiated in prior years were completed. The SWFSC Dolphin Energetics Program continued to focus on investigating potential effects of tuna purse seine set evasion on dolphin mothers and calves. Field work was completed for a dolphin swimming kinematics study, which entailed collecting digital video of three dolphin mothers from late-term pregnancy through two years postpartum and of four dolphin calves (one calf from two weeks postpartum and the other three calves from birth) through two years postpartum. The final (two years postpartum) videos were collected in November 2005. Analysis of the digital video provides data for determining swim speed and effort (fluke stroke amplitude and velocity) of dolphin calves swimming in echelon and independently, and of dolphin mothers during near-term pregnancy and non-pregnant.

The study estimating velocity duration limits for ETP spotted dolphin calves swimming unassisted indicated that dolphin calves up to at least two years of age are likely to have difficulty sustaining speeds typical of tuna purse seine set evasion. Estimated power requirements for neonates are about four times higher than adult power requirements to maintain any given speed. Even at two years of age, power requirements for calves are 50% higher than adult levels. Therefore, calves, particularly the younger, smaller individuals, will tire much more quickly than the adults during fishery interactions when swimming unassisted.

The review of dolphin calf behavioral and physiological development indicates that ETP dolphin calves up to at least 12 months postpartum are likely to have physiological difficulty remaining near or reuniting with their mothers during evasion of tuna purse seine sets, and that behavioral dependence on the mother is likely to persist through at least two years of age.

The study of dolphin calf swimming kinematics from birth through one month postpartum demonstrated that dolphin calves in echelon position can swim significantly faster and farther with less effort than dolphin calves swimming unassisted. Results indicate that 0- to 1-month-old calves cannot maintain proximity to the mother unless in echelon position, even at normal (non-chase) swim speeds.

The combined message from these studies is that dolphin calves, particularly during the early months, are quite likely to have difficulty maintaining proximity to their mothers during fishery evasion and are at substantial risk of unobserved fishery-related mortality if permanently separated from their mothers before two or three years of age.

Non-depleted ETP Cetaceans – Refinement of ETP common dolphin life history analyses continued in 2005. Spatial and temporal analyses of length and age data in combination with oceanographic data revealed that common dolphin stock boundaries may be fluid during significant environmental events. Specifically, northern or southern stock animals may move into the Costa Rica Dome area during El Niño events in search of more favorable habitat.

Bycatch Reduction Workshops – The first in what is planned to be a series of workshops was convened in May 2005 as a joint effort of the SWFSC and the IATTC to discuss potential methods for reducing non-dolphin bycatch in the ETP tuna purse seine fishery.

Participants in the first workshop discussed several research proposals; three proposals were selected by the participants for further development and review by experts during a second workshop planned for summer 2006. Proposal ratings were based on the expected conservation benefit and the degree to which each proposal was cost-effective. The three proposals selected for evaluation during the second workshop were: (1) use of existing data to identify time-area closures to reduce bycatch; (2) use of deterrents or attractants to avoid capture of sharks in sets made around fish aggregating devices (FADs); and (3) modification of FAD design to reduce turtle entanglement. A fourth proposal that combines a number of proposals requiring ship time from the first workshop has also been prepared. In addition, the SWFSC provided initial funding to the IATTC to conduct a pilot study of the second proposal described above; results from this pilot study are not yet available.

The four proposals described above will serve as the basis for discussion during a summer 2006 workshop. This workshop is being funded by the NMFS Southwest Region and is a joint effort between the SWFSC, Southwest Region and IATTC. The primary goals of the this workshop will be to conduct a technical review of the four formal research proposals described above, discuss the strengths and weaknesses of each proposal, and determine a hierarchy of proposals for funding, when funding becomes available.

Port Sampling and Observer Program to Monitor Small Purse Seine Vessels – The Agreement on the International Dolphin Conservation Program (AIDCP) requires observer coverage aboard 100% of the trips made by international large purse seine vessels (i.e., those in excess of 400 short tons carrying capacity) in the ETP. However, approximately one quarter of all the vessels in the ETP purse seine fishery are smaller than this threshold. While these vessels are prohibited from harvesting tuna by chasing and encircling dolphins, they are not required to carry observers. The absence of observer data to confirm the fishing practices of small purse seine vessels and data indicating that depleted dolphin stocks in the ETP are not recovering at the expected rate has led to concern among the AIDCP Parties, particularly that data are needed to confirm that these vessels are fishing in accordance with the AIDCP.

To learn more about the fishing practices of these vessels, the SWFSC awarded a contract to the IATTC to expand the at-sea observer and in-port sampling programs currently implemented in the ETP tuna purse seine fishery under the AIDCP. The contract provides for placement of observers onboard 1,000 sea days of currently unobserved, international small purse seine vessels (approximately 20% of expected Class 5 sea days) and for species and size composition sampling of landed catch for all Class 4 and 5 vessels in the fleet.

As of April 30, 2006, 54 unloadings by Class 4 and 5 vessels in international ports have been sampled under this contract. No AIDCP Party with small purse seine vessels has agreed to the placement of at-sea observers at this time.

This contract has the potential to yield important data on the fishing practices and associated impacts of small purse seine vessels from which a limited amount of information is currently collected. Data collected under this contract will be evaluated and analyzed further during 2006 to determine whether this work should continue and what, if any, new information can be gleaned about the activities of these vessels.

Research Planning – In 2005 and 2006, SWFSC staff drafted a proposal titled "Long-term Research in the Eastern Tropical Pacific," which consists of detailed proposals for the fishery effects studies, as well as the population monitoring studies and ecosystem studies that together comprise our overall ETP work. The intent of the proposal is to guide future research. The proposal contains detailed budgets and structures work into the following areas: (1) assessments of status and trends; (2) abundance and monitoring of pelagic dolphin populations; (3) cetacean stock structure in ETP pelagic waters; (4) abundance, structure and monitoring of coastal dolphin stocks; (5) ETP ecosystem studies; (6) fishery effects; (7) bycatch reduction; and (8) data management.

The SWFSC is currently working to schedule an external review of these proposals by the Center for Independent Experts at the University of Miami. This review is likely to be completed during the summer of 2006. It is intended to subject these proposals to formal external review and use them as the basis for guiding future research.

VI. PELAGIC SHARK RESEARCH

The SWFSC's shark research focuses on highly migratory pelagic sharks that occur along the U.S. Pacific Coast, including shortfin mako, blue shark, and three species of thresher shark. Researchers are studying the sharks' biology, distribution, movements, stock structure and status, and potential vulnerability to fishing pressure. This information is provided to international, national, and regional fisheries conservation and management bodies having stewardship for shark and highly migratory species. Some of the recently completed or ongoing shark research activities being carried out by the SWFSC are discussed below.

Shark Surveys – Thresher and mako sharks are important commercial sharks in California and popular sport species, especially in highly populous southern California. Although the blue shark has little market importance in the United States, it is a leading bycatch species in the U.S. West Coast drift gillnet and high-seas longline fisheries. Surveys are carried out in the Southern California Bight to track trends in abundance of juvenile and sub-adult blue and shortfin mako sharks and neonates of common thresher shark. The commercial and sport catch of these species within U.S. Pacific Coast waters consists largely of juvenile sharks, although catches of adult blue and thresher sharks and a few adult shortfin mako sharks also occur. Efforts to determine abundance trends from commercial fishery data have so far been complicated by changes in fishing methods and areas and regulatory restrictions over time, which have resulted in wide swings in both catch rate and catch distribution that are difficult to interpret. Therefore, consistent, fishery-independent sampling was needed, with slightly different survey strategies required for the more oceanic shortfin mako and blue shark compared to the more coastal common thresher shark.

Offshore longline surveys from relatively large research vessels have proved most appropriate for sampling and estimating abundance trends of the more oceanic species (shortfin mako and blue sharks). The surveys have enabled the SWFSC to obtain a valuable abundance index for the shortfin mako, which can be linked to a historical time series of logbook and landings data from a former experimental shortfin mako longline fishery in the Southern California Bight which occurred during 1988-91. Abundance trend information is also obtained for the blue shark, which is compared to information obtained from observers in the California/Oregon drift gillnet and Japanese high-seas longline fisheries. The surveys are carried out cooperatively with the California Department of Fish and Game and Mexican researchers from CICESE in Ensenada, Mexico. Tagging is also carried out to determine shark movements and obtain information on shark age and growth.

Surveys for neonate thresher sharks are conducted using small commercial driftnet and longline vessels. Initial studies demonstrated that neonate threshers are rarely encountered in waters deeper than about 90 m. Therefore, surveys are conducted in the shallower nearshore waters between Point Conception, California, to the north and the U.S.-Mexico border to the south. The primary purpose of the surveys is to produce a relative abundance index for the West Coast population of the common thresher shark by periodically sampling 0-year pups (neonates) in their core nursery grounds off southern California. Once the nursery area is defined, representative core areas will be identified and sampled annually. The resulting neonate index of abundance should mirror adult abundance because adult population and recruitment should be tightly linked in K-selected species such as sharks. This study will

complement the fishery-dependent data available through the observer program to provide measures of relative and absolute abundance of common thresher shark for stock assessment models.

Juvenile Mako and Blue Shark Abundance Survey – In 2005, the SWFSC juvenile shark survey deployed a total of 5,719 hooks at 28 sampling stations off southern California. This was the 12th year for the survey, which provides a time series of CPUE, length-frequency and life history data for shortfin mako and blue sharks needed to address issues of stock condition. The index of relative abundance for juvenile sharks defines CPUE as catch per 100 hook-hours and summarized by set. Catch for the 2005 survey included 80 mako, 101 blue and 2 common thresher sharks, and 12 pelagic rays. The catch-effort data indicate the overall catch rate was 0.37 sharks per 100 hook-hours for shortfin mako and 0.44 sharks per 100 hook-hours for blue sharks (Fig. 1). Catches of shortfin mako varied from 43 sharks in 2000 to 189 sharks in 2001, and catches of blue shark varied between 73 individuals sampled in 2002 to 903 individuals sampled in 2000. Since 1995, there has been a continual decline in CPUE at the 408 stations that sampled shortfin mako sharks, from a high of 1.03 sharks per 100 hook-hours in 1994 to less than 0.5 sharks per 100 hook-hours in the last three years. The CPUE trend for blue sharks likewise decreased over the period but with greater variability. These trends do not necessarily indicate a serious decline in abundance; however, further monitoring should continue.

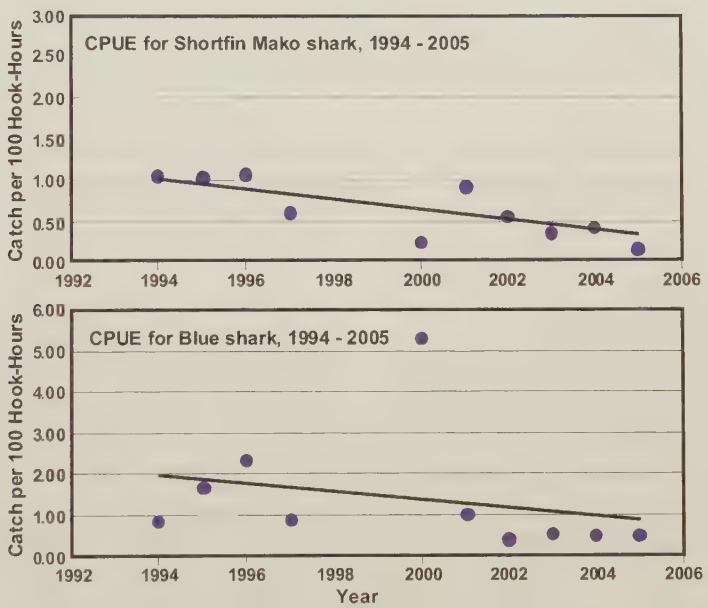

Figure 1. Catch per 100 hook-hours for shortfin mako and blue sharks, 1994-2005.

Neonate Common Thresher Shark Abundance Surveys – The common thresher shark pre-recruit index and nursery ground survey was begun in 2003. During fiscal year 2004, the first year of the study, 16 trips were completed (6 gillnet and 10 longline). In 124 longline sets, 103 common thresher sharks were captured, 34 of which were neonates. In 29 gillnet sets, 83 common thresher sharks were captured, 37 of which were neonates. Neonates were captured in most sampled areas, including off San Diego, Carlsbad, Santa Barbara and Gaviota, California. Depth-stratified sampling revealed that over half of the neonates were caught in shallow waters of 0-46 m. During the first year,

various longline gears (e.g., hook size, bait, hooks per set) were utilized to determine the most effective gear for sampling neonates. Further longline sampling has since been done with standardized gears.

During fiscal year 2005, the survey efforts included 29 nearshore driftnet sets and 38 nearshore longline sets. Overall, 15 common threshers, 21 shortfin makos and 20 blue sharks were caught. Analysis on trends in CPUEs as an abundance index will require a few more years of data to be meaningful. Due to the patchy distribution of neonates, increased effort may be necessary. The thresher shark pre-recruit survey provides the opportunity to enhance other ongoing studies of the SWFSC shark research group, such as age and growth, feeding, and habitat utilization studies.

Pelagic Shark Migration Studies – Blue and mako sharks are caught in high-seas fisheries and in smaller scale fisheries operating off the West Coast of the United States and Mexico. To properly manage and understand their oceanic and coastal distributions with respect to the fisheries, SWFSC scientists have been using satellite telemetry to study the vertical and horizontal movement patterns of sharks in collaboration with the Tagging of Pacific Pelagics program and scientists at CICESE. During 2005 and early 2006, 10 makos, 15 blue sharks, and 5 threshers were tagged with pop-off archival tags (PAT tags) and/or near real-time satellite-linked radio transmitters (SPOT tags). Since 1999, a total of 44 makos, 46 blue sharks, and 20 common threshers have been satellite tagged through these collaborative projects. Preliminary analysis of the movements of mako and blue sharks was presented in May 2005 at the Symposium on Fishery Sciences in Mexico. Figure 2 shows combined horizontal movements of both blue and mako sharks for the years 2002 through April 2006. In general, both sharks seem to be wide-ranging; however, blue sharks spend more time at depths exceeding 100 m than do mako sharks. A summary of the blue shark diving behavior from animals tagged in 2002 and 2003 was recently published as a comparison to movements of salmon sharks in the North Pacific.

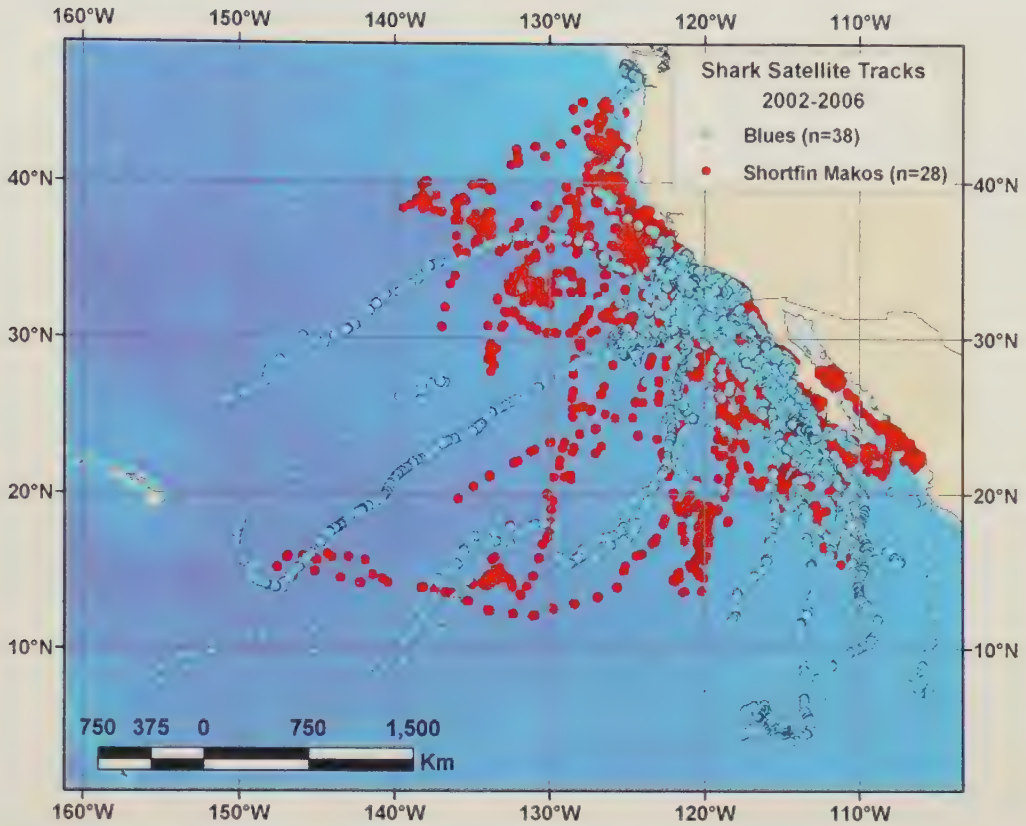

Figure 2. Horizontal movements of shortfin mako and blue sharks tracked with fin-mounted satellite-linked radio transmitters.

Movements of the common thresher shark were described in the master's thesis of Andres Baquero of the University of San Diego, completed in December 2005. A manuscript of the results is in preparation. Figure 3 shows the horizontal movement of six threshers tagged in 2004 and 2005. In comparison to the mako and blue sharks, the threshers spent most of their time in nearshore waters. Figure 4 shows the diving behavior during a one-week period of one shark from which an archival tag was recovered. The animal exhibited a diurnal pattern of diving during the day while staying closer to the surface at night. These are the first detailed movement data from common thresher sharks in this area and along with the survey data will help to define the common thresher shark essential habitat.

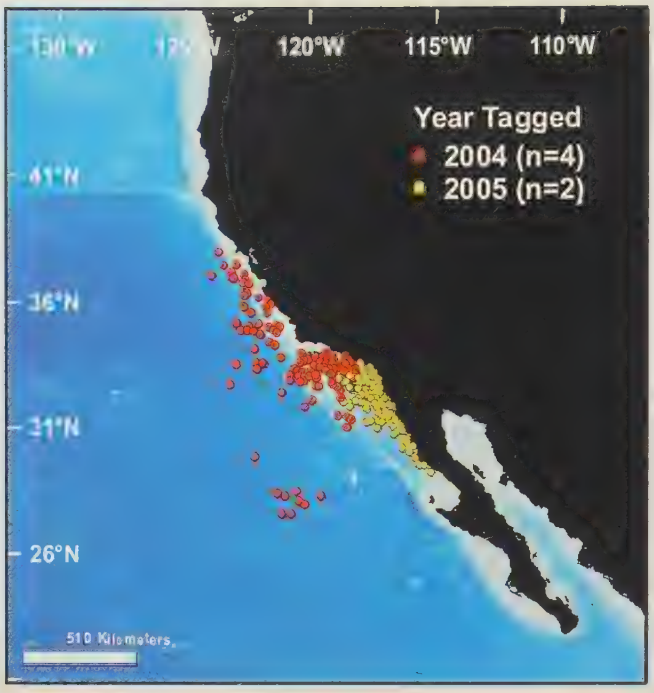

Figure 3. Light and sea surface temperature-based location estimates for movements of 6 thresher sharks tagged with pop-off archival tags in 2004 and 2005.

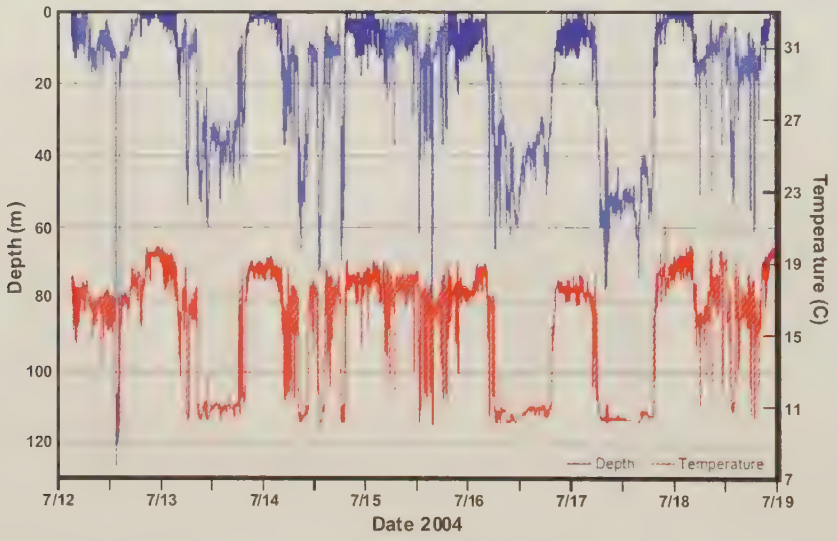

Figure 4. Diving behavior of a common thresher shark during a one-week period.

Pelagic Shark Feeding Ecology – Since 1999, work has continued investigating the feeding ecology of the common thresher shark during various oceanic regimes. The results of these studies have been published as two articles in CalCOFI Reports.

Recent work has focused on a comparison of blue, shortfin mako, and common thresher shark diets when these species co-occur in California Current waters off California, Oregon and Washington. The study is in the fourth year of sampling and

analysis. Of 115 mako shark stomachs examined, 81 contained prey representing 23 taxa. Jumbo squid (*Dosidicus gigas*) and Pacific saury (*Cololabis saira*) were the two most important prey items. Of 97 blue shark stomachs examined, 67 contained prey representing 24 taxa. Cephalopods of the *Argonauta* spp. and *Gonatus* spp. were the most important prey items. Of 89 thresher shark stomachs examined, 55 contained prey representing 18 taxa. Pacific sardine (*Sardinops sagax*) and northern anchovy (*Engraulis mordax*) were the two most important prey items. Comparing the first 12 prey items ranked by GII for each species, results demonstrate that mako sharks fed on a combination of different taxa of teleosts and cephalopods, blue sharks fed primarily on different cephalopod species, while threshers consumed mostly teleosts, especially coastal pelagic species, and very little squid. The analyses are ongoing to determine whether there were interannual differences in the main prey items consumed and to examine correlations between the diets and potential prey availability or prevailing oceanographic conditions.

Mako and Thresher Shark Age, Growth and Maturity – Age and growth of mako and thresher sharks are being analyzed by ring formation in recaptured animals with OTC-marked vertebrae. Four hundred eighty-eight OTC-marked individuals have been released during the juvenile shark surveys and 28 have been recovered (5.7%). Of those 28, vertebrae were collected from 18 sharks. Time at liberty ranged from 7 to 1,594 days with net movements of individual sharks as high as 2,648 nmi. Preliminary results from shortfin mako vertebrae indicate that juvenile and sub-adults lay down two bands of unequal size each year; however, as they mature and transition from a more coastal distribution to more oceanic, the calcification pattern in the vertebrae appears to change, with hyaline and calcified zones becoming narrower and more equal in relative size. This is an extremely interesting finding, since the question of whether the shortfin mako lays down one band or two bands per year has been an ongoing uncertainty, with two independent labs reporting conflicting results.

Thresher shark vertebrae are also being aged at the SWFSC using X-radiography techniques. The purpose is to expand and refine previous thresher shark ageing studies using a larger sample size from the driftnet fishery with accompanying information on sex and maturity stage. Tetracycline marking and release of tagged juvenile and sub-adult thresher sharks off California has begun to verify the timing of ring formation. Preliminary results from common thresher sharks indicate that they lay down one band per year.

Ageing studies are also underway to determine age and growth of shortfin mako sampled by Japanese longline from widely distributed localities in the Pacific and common thresher shark from the California/Oregon driftnet fishery. Mako shark growth rates and age are being examined using non-marked vertebrae collected from the California drift gillnet fishery and from Japanese longliners. The vertebrae are sectioned, X-rayed, and imaged using a Spot camera and microscope. The study will use the criteria developed in the validated (OTC-marked) ageing study for mako and thresher sharks along with the length-frequency distribution of the catches of the California drift gillnet fishery and the Japanese longline fleet. The derived ages and growth rates will be compared to determine differences in stock structures and to help elucidate migratory patterns. This project is being conducted cooperatively with Hideki Nakano of the National Research Institute of Far Seas Fisheries, Japan. Goals of this study include determining the mako and thresher sharks' size and age at maturity and defining the age structure of sharks caught off the U.S. West Coast.

The results from these studies should validate the age estimates of the shortfin mako and the common thresher shark and clarify how to interpret the formation of vertebral growth bands for these two species. The criteria for determining annual growth increments as determined by OTC validation will create the opportunity to obtain more accurate life history information which is needed for fisheries management. Several areas of uncertainty remain. For example, the growth model needs to be developed from a larger sample size with specimens that have made the transition from immature to mature.

Blue Shark Dynamics in the U.S. Pacific Coast EEZ – The objective of this project is to develop a model of blue shark preferred habitat based on longline and drift gillnet catch statistics and environmental data. A statistical model will be created to show how blue shark CPUE varies spatially and temporally. Secondarily, this model will attempt to validate Hideki Nakano's hypothesis, which states that blue sharks are segregated latitudinally by sex and age class, and verify whether it pertains within the U.S. EEZ. The capture rate of blue sharks in the California drift gillnet fishery is second highest after the ocean sunfish, yet their meat is not marketable. One targeted swordfish is caught for every 1.1 blue sharks. Finally, the predictive model will be compared to the distribution of swordfish catch to determine the degree to which they coincide. Determining the spatial and temporal distribution of these sharks with respect to remotely measured environmental variables such as sea surface temperature and chlorophyll may enable fisheries managers to apply appropriate measures to limit their bycatch.

Bioaccumulation of Mercury in the Common Thresher and Shortfin Mako Shark – The common thresher and shortfin mako shark, being apex predators, have the potential to bioaccumulate high concentrations of methyl mercury in their tissues. These shark species are actively fished commercially along the U.S. West Coast and are marketed for human consumption. Despite this potential human health risk, there are no comprehensive published studies of the mercury levels in these fish. A 1991 preliminary study by the Hawaii Department of Health found high levels of mercury in the market fillets of shortfin mako with an increase in fish size. The mean mercury level was 1.32 ppm per serving, which exceeds the Food and Drug Administration's recommended safe human consumption levels of 1.0 ppm. The fish sampled in this study were generally larger than the mako sharks caught in the West Coast drift gillnet fishery. Similarly, the same preliminary study also found high levels of mercury (mean = 1.02 ppm) in two species of thresher shark (pelagic and bigeye).

The goal of this study is to describe the bioaccumulation of mercury with size and sex for the shortfin mako and common thresher shark in the eastern North Pacific and determine if mercury levels in West Coast market-size fish are a cause for concern for human consumption. We will also investigate for evidence of suspected ontogenetic diet shifts and the feasibility of utilizing mercury level as an indicator of trophic status complementing the stable isotope study (described below).

Preliminary results show low levels of mercury in the muscle tissue of small juvenile common thresher sharks. Tissue samples from larger individuals are now available and are being analyzed. In contrast, the lone neonate shortfin mako analyzed to date shows a high mercury level (1.16 ppm) and three large adult makos had very high mercury levels (mean = 2.90 ppm).

Feeding Ecology and Trophic Status of the Common Thresher and Shortfin Mako Shark Inferred from Stable Isotope Analysis – The common thresher and shortfin mako shark are suspected of undergoing ontogenetic diet shifts, but there is little quantitative evidence to support this. There is an ongoing SWFSC food habits study of these two shark species using stomach content analysis. Despite its high resolution, with the inherent snapshot view bias of stomach content analyses, it would take large sample sizes and sampling throughout the year, if such feeding events are rare and/or localized spatially or temporally, to have a good chance capturing such differences in the feeding of these fish. Stable isotope signatures in a consumer reflect those of their diet with some fractionation (i.e., enrichment). Stable isotope signatures are a cumulative record of the feeding events of an individual fish and the temporal aspect of this depends on the isotopic turnover rate of the particular tissue examined.

The goal of this study is to infer aspects of the feeding ecology and trophic status of the common thresher and shortfin mako shark from the eastern North Pacific using stable isotope analysis of tissues and vertebral centra. This study will complement and supplement the SWFSC shark research group's pelagic shark food habits study.

Population Structure of Shortfin Mako – The shortfin mako is an extremely wide-ranging pelagic shark that is reported to occur throughout temperate and tropical waters worldwide. In the North Pacific, the shortfin mako is encountered in fisheries off the coasts of North America, Japan, and throughout the north central Pacific. In the South Pacific, makos are commonly encountered in fisheries operating off Australia, New Zealand, Peru, and Chile. Conventional tag returns have demonstrated that individual sharks tagged in southern California waters have migrated as far as Hawaii; Acapulco, Mexico; and Japan. In the North Atlantic, where conventional tagging of shortfin makos has a longer history, of 608 tags returned not a single shark was recaptured south of 10°N. This study will test the hypothesis that shortfin makos from the North and South Pacific are genetically distinct. Population structure of shortfin mako in the Pacific Ocean will be inferred through mitochondrial DNA analyses. Samples are being collected throughout the Pacific Basin through cooperation with fisheries scientists in New Zealand, Australia, Chile, and Japan, and by the SWFSC shark research group at La Jolla through surveys and fishery observers in southern California. DNA is being extracted and examined for mtDNA variability at the sequence level. In addition to examining distinctions between North and South Pacific populations, this study will address, based on the mtDNA sequences, if mako sharks are philopatric; specifically, are the females returning to the same area to give birth each year as has recently been shown in other shark species through DNA analysis. A better understanding of stock structure is critical to developing accurate stock assessments and improves fisheries management of this species.

VII. BILLFISH RESEARCH

This year marks the 42nd year that the NMFS and the billfish angling community have combined efforts to measure angler success for billfishing. These efforts have created one of the longest time series available for recreational billfishing, charting trends in relative abundance for key species. With highly migratory species management unfolding in both the eastern and western Pacific, data series such as these are key to assessing the health of the stocks. The SWFSC remains committed to monitoring recreational billfishing success. This research includes recreational and commercial fishery monitoring, stock assessments, biological research into the life history and ecology of specific billfish

species, and determining the economic importance of billfish resources. Two major components of that research are the International Billfish Angler Survey and the Billfish Tagging Program. These programs produce essential information pertaining to the recreational billfish angling community for exploring conservation and management concerns.

Billfish Angler Survey – The SWFSC continued monitoring recreational billfish catch in the Pacific through its Billfish Angler Survey. Results for recreational fishing in 2004 were compiled in 2005 and published in the 2005 Angler Survey. In 2004, 761 billfish anglers reported catching 3,409 Pacific billfish during 4,988 fishing days. The mean CPUE for all billfish in the Pacific for 2004 was 0.66, which is lower than the record set in 2003 of 0.87 but above the latest five-year average of 0.62 (2000-04). This was a new high five-year average catch rate for the entire time series, which extends back to 1969. CPUE times series were extended for each of the main species caught (Pacific blue marlin, striped marlin, Pacific sailfish, and black marlin) in the main fishing areas (Tahiti, Hawaii, Baja, southern California, central Mexico, Guatemala, Costa Rica, Panama, and Australia). Figure 5 shows the CPUE time series by region for the four major species caught.

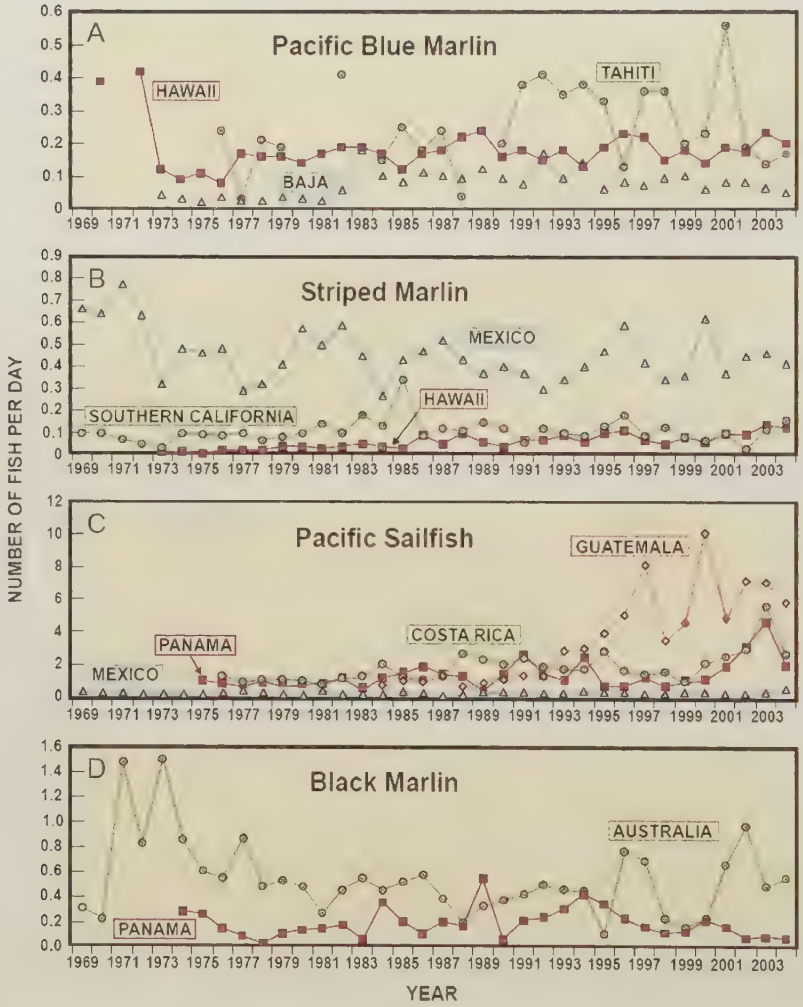

Figure 5. CPUE time series for the 4 major species reported through the Billfish Angler Survey.

Recreational Billfish Tagging Program – The SWFSC's Billfish Tagging Program began in 1963 and has provided tagging supplies to recreational billfish anglers for 42 continuous years. Tag release and recapture data are used to determine movement and migration patterns, species distribution, and age and growth patterns of billfish. This volunteer tagging program depends on the participation and cooperation of recreational anglers, sport fishing organizations, and commercial fishers. Since inception, over 53,000 fish of 75 different species have been tagged and released. Emphasis continues to be on the skillful tagging of billfish and bluefin tuna only. The tagging of other sport fish is not encouraged by this program. Billfish Tagging Report cards received for 2004 indicate that a total of 1,047 billfish and 285 other fish were tagged and released by 761 anglers and 190 fishing captains. In all, 525 blue marlin, 149 striped marlin, 217 sailfish, 137 spearfish, 6 black marlin, and 9 unknown billfish were reported tagged and released in 2004. Table 1 shows the tagging effort for 2004 and the tag recoveries throughout the program's history.

Species Name	Release 2004	Release Total	Return Total	Rate %
Striped Marlin	149	21,784	336	1.54
Sailfish	217	8,684	49	0.56
Pacific Blue Marlin	525	7,322	74	1.01
Marlin, unid.	8	4,303	3	0.07
Black Marlin	6	3,356	69	2.06
Mako Shark	131	1,597	52	3.26
Short-billed Spearfish	137	1,584	2	0.13
Broadbill Swordfish	0	520	17	3.27
Blue Shark	38	374	6	1.60
Yellowfin Tuna	0	347	24	6.92
Com. Thresher Shark	89	169	9	5.33
Skipjack Tuna	0	97	2	2.06
Albacore Tuna	0	87	1	1.15
Thresher Shark	7	63	2	3.17
Bluefin Tuna	0	57	8	14.04
Hammerhead Shark	0	53	2	3.77
Whitetip Shark	3	43	1	2.33
Marlin, Atlantic Blue	0	41	0	0.00
Salmon Shark	0	27	0	0.00
Billfish, unid.	1	24	2	8.33
Silky Shark	18	18	0	0.00
Tiger Shark	0	15	0	13.33
White Marlin	0	13	1	7.69
White Shark	0	9	0	0.00
Shark, Basking	0	7	0	0.00
Whale Shark	0	4	1	25.00
Longbill Spearfish	0	3	0	0.00
Pelag. Thresher Shark	2	3	0	0.00
Other Tunas	0	94	3	3.19
All Others	1	2,315	84	3.63
Totals	1,332	53,013	748	1.41

Table 1. Summary of all fish tagged through the Billfish Tagging Program in 2004 with releases and recoveries for 1963-2004.

Adopt-a-Billfish Tagging Program – In 2002, scientists from the SWFSC and NMFS Southeast Fisheries Science Center joined forces with the Presidential Challenge billfish tournament series conducted off the coasts of Central America and Mexico to establish the Adopt-A-Billfish satellite tagging program. The team deployed 41 satellite archival

tags on sailfish in Mexico, Guatemala, Costa Rica and Panama. Results show that sailfish survive being caught and released when proper tagging protocols are followed. Three of the 41-tagged sailfish died, but only after being at liberty for 28, 63 and 70 days after being tagged. The data also showed significant movements across international boundaries from Mexico to Panama, highlighting the need for international management. Deployments ranged from 5 to 118 days and net movements ranged to 574 nmi. These sailfish spent up to 80% their time at depths above 25 m and rarely descended to depths greater than 100 m. Over 75% of their time was in water 28°C to 30°C. The program plans to expand sailfish satellite tagging operations into the mouth of the Sea of Cortez, Mexico, in the summer of 2006.

Molecular Identification of Billfish Eggs and Larvae – Ichthyoplankton samples are collected on most SWFSC cruises and have been collected at least yearly since 1951. These samples provide an excellent time series and are good indicators of environmental shifts and trends in distribution and abundance of a variety of species. Traditionally, samples are collected at sea and preserved in formalin then are brought back to the lab for sorting and identification. Identifications are generally made using a microscope and are based solely on morphology and pigmentation. This is an extremely labor intensive process, and few scientists possess the requisite expertise to identify eggs and larvae. In addition, one survey can take four to six months to process, with 90% of the samples remaining unidentifiable.

The SWFSC Fisheries Resources Division has pioneered a new technique to not only improve our ability to identify ichthyoplankton samples but to do so in real time, at sea. Samples can be collected using net tows or the continuous underway fish egg sampler (Fig. 6). With an automated molecular technique, eggs and larvae are processed and identified on board the ship, within hours of collection.

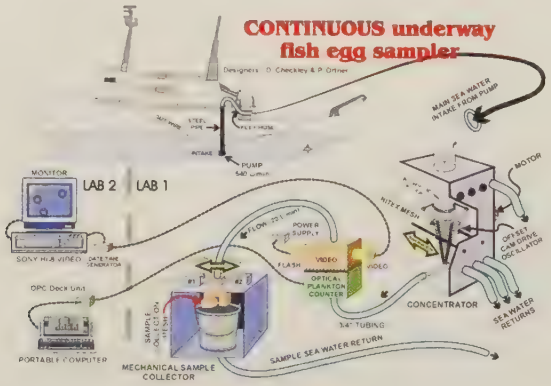

Figure 6. Schematic diagram of the continuous underway fish egg sampler.

In collaboration with the Pacific Islands Fisheries Science Center, this new method has been field tested on four cruises during July and September 2004 and March and May 2005 off the Kona coast of Hawaii, a putative spawning "hot spot" for istiophorid and xiphiid billfish. A species-specific multiplex PCR assay was designed to amplify a single, unique size fragment of the mitochondrial cytochrome *b* gene for all six species of Indo-Pacific billfish, both dolphinfish species, and the monospecific wahoo. Eggs and larvae were successfully identified to species within three hours of acquisition (Fig. 7).

This study provided the first description of the eggs of blue marlin, shortbill spearfish and wahoo and is helping to determine the spatial and temporal dimension of spawning and nursery habitats of these highly valuable but poorly known species. Additionally, during the May 2005 cruise, striped marlin larvae were found off the Kona coast. Though there is a predominance of striped marlin in longline catches, this is the first documented occurrence of their spawning in Hawaiian waters.

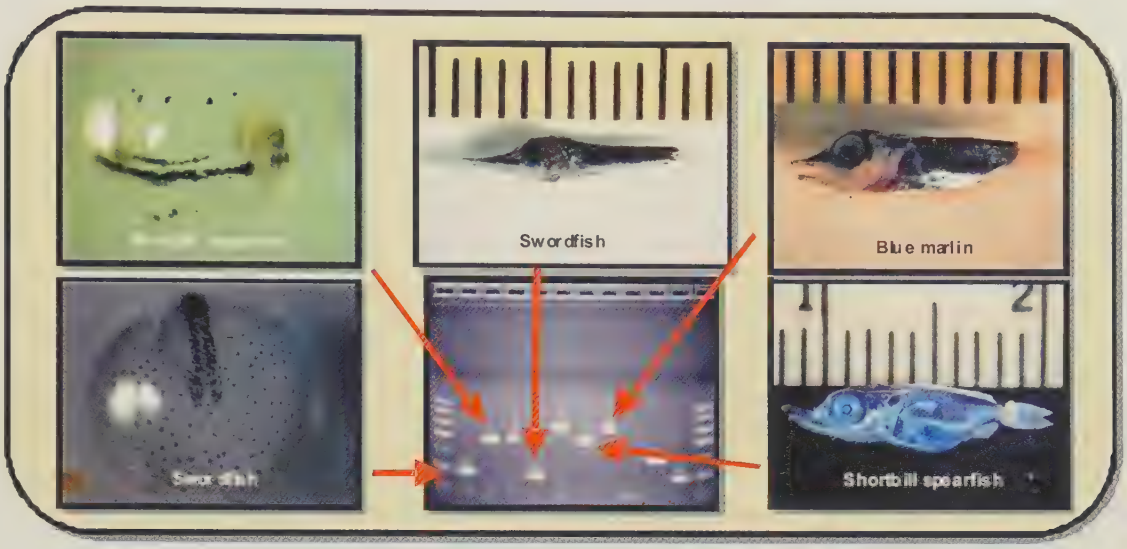

Figure 7. DNA-specific probes and optical detection identify eggs and larvae.

Fourth International Billfish Symposium – Scientists at the SWFSC helped organize and participated in the 4th International Billfish Symposium held on Santa Catalina Island October 31 to November 3, 2005. Results of the sailfish tagging efforts conducted through the Adopt-a-Billfish tagging program as well as the billfish larval molecular identification were presented.

Collaboration on North Pacific Striped Marlin Research – In 2005, marlin assessment research at the SWFSC focused on striped marlin to meet the ISC Marlin Working Group goal of completing a North Pacific striped marlin assessment in 2005. SWFSC scientists participated in two ISC Marlin Working Group meetings. Before and at the first meeting in September 2005, the SWFSC team helped to prepare a database of international landings, catch and effort, and size frequency. At the meeting, the available data were reviewed and potential modeling platforms were identified to be used for the assessments. The SWFSC took the lead in developing a fully integrated forward simulation model using Stock Synthesis 2. Results of the working group's assessment efforts will be presented at the 2006 ISC Plenary meeting.

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